THERMIONIC FIELD EMISSION FROM UNCD COATED TIP STRUCTURES

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Keywords: UNCD, diamond, field enhancement, thermionic emission, field emission microscopy

Abstract

Current studies involving thermionic energy converters point to crystalline carbon films in combination with field enhancing properties as promising candidates for the emitting material [1]. Thermionic energy conversion is accomplished through the combination of a hot electron emitter in conjunction with a somewhat cooler electron collector. In operation, an electric potential will develop between the two surfaces that can result in a significant source of electrical energy. The system converts the thermal energy into electrical energy. Since the process is based on electron emission and collection with no mechanical motion, this source can be highly efficient and operate without maintenance for extended periods of time. A limiting phenomenon to the vacuum emission of electrons is the space charge effect in which electrons in the vacuum close to the emitter surface impede additional electron emission. A method to combat this limiting effect is the introduction of surface features which produce a field enhancement effect at the surface. The electrons emitted from the tip shaped surface features are accelerated more rapidly across the vacuum gap to the electron collector.

Ultra nanocrystalline diamond (UNCD) films have been grown on etched Silicon tip arrayed substrates. Raman spectroscopy of the films shows peaks consistent with typical UNCD films and SEM shows continuous coating of the underlying array and clear field enhancement geometry. Field emission electron microscopy (FEEM) measurements of the tip arrayed films give real time, spatially resolved images of temperature dependent electron emission. The first significant emission above room temperature emission occurs at temperatures around and below 830º C. In this regime, an intense, temperature dependence is observed from both the tip structures of the sample as well as the flat, background areas (Figure 1). Field enhancement affects the intensity of emission resulting in brighter spots at the apex of the tips. This emission reaches its strongest around 830º C, rapidly degrading for temperatures in excess of this maximum. This temperature dependent degradation in emission has been observed for other nitrogen doped crystalline CVD films and is correlated to the desorption of surface bound hydrogen and the linked loss of the film's negative electron affinity (NEA)[2]. As the temperature is further increased, intense emission is once again observed from the tips of the sample (Figure 2). This emission is stable and cyclic and present only at the tips of the array. There is no contribution from the background. In this presentation, the origin of these electron emission regimes will be examined and explained.

References

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2. Koeck, F.A.M., et al., "Enhanced low-temperature thermionic field emission from surface-treated N-doped diamond films," *Diam. Relat. Mater.*, Vol. 11, 774 (2002).

Figures

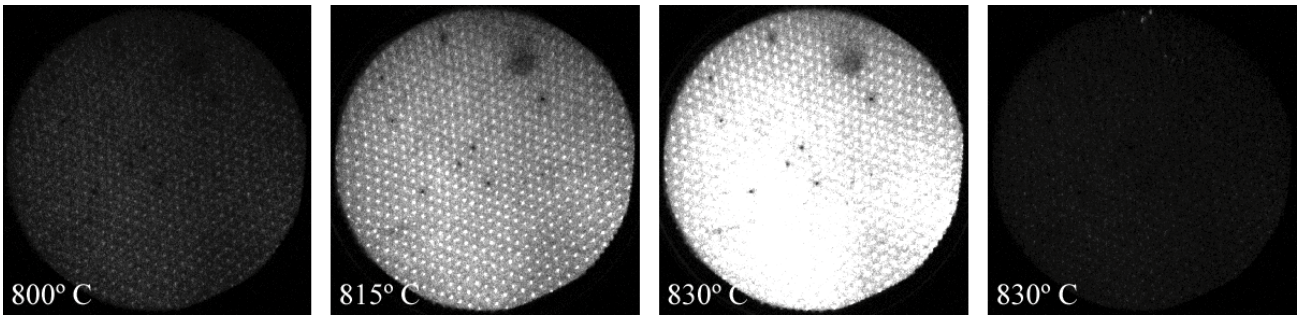

Figure 1. Temperature dependent FEEM images of the UNCD coated tip array. A steady increase in electron emission with increasing temperature is observed up to 830º C. Electron emission is detectable from both the tips and flat background of the sample. The geometric field enhancement effect results in stronger emission from the apex of the tips as compared to the background. After five minutes of exposure to the elevated temperature, the emission degrades. This corresponds to a loss in the film's NEA due to hydrogen evolution from the surface.

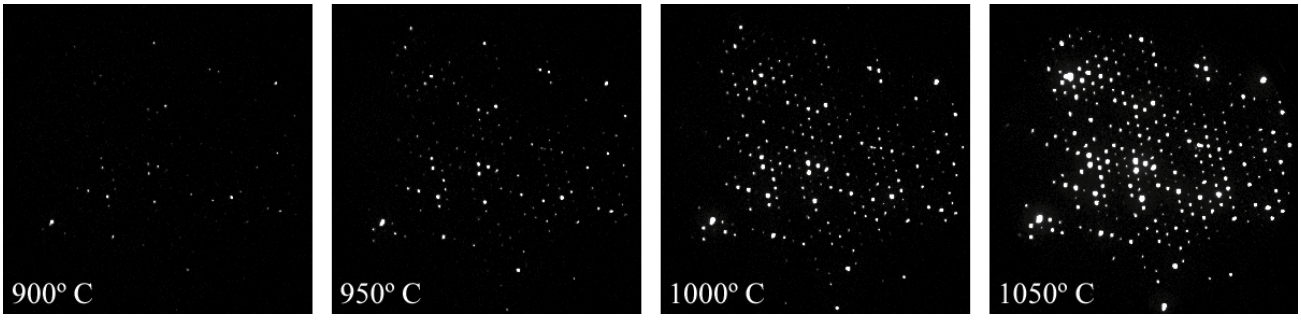

Figure 2. After the loss of the film's NEA, temperature dependent field emission continues to be present. As the sample is annealed to higher temperatures, strong electron emission is observed from the tips of the array. There is no longer detectable emission from the flat background of the sample. This emission is very stable and repeats with successive increasing and decreasing sweeps of the temperature.